Sensornetzarchitektur zur Erfassung von Bodendaten und zur Bestimmung der Biomasse

Rolf Kraemer

13.09.2017

innovations
for high
performance
microelectronics

Member of
Leibniz Association

Outline

Das IHP – Unser Gebäude

IHP at a Glance

Institute of the Leibniz Association

- 320 people from 30 countries, including 134 scientists
- Founded in 1983
- Owner is the State of Brandenburg

Financing 2016

- Basic funding from the German and local government: 28.9 Mio. Euro
- Third party funds: 19.2 Mio. Euro

Main Activities

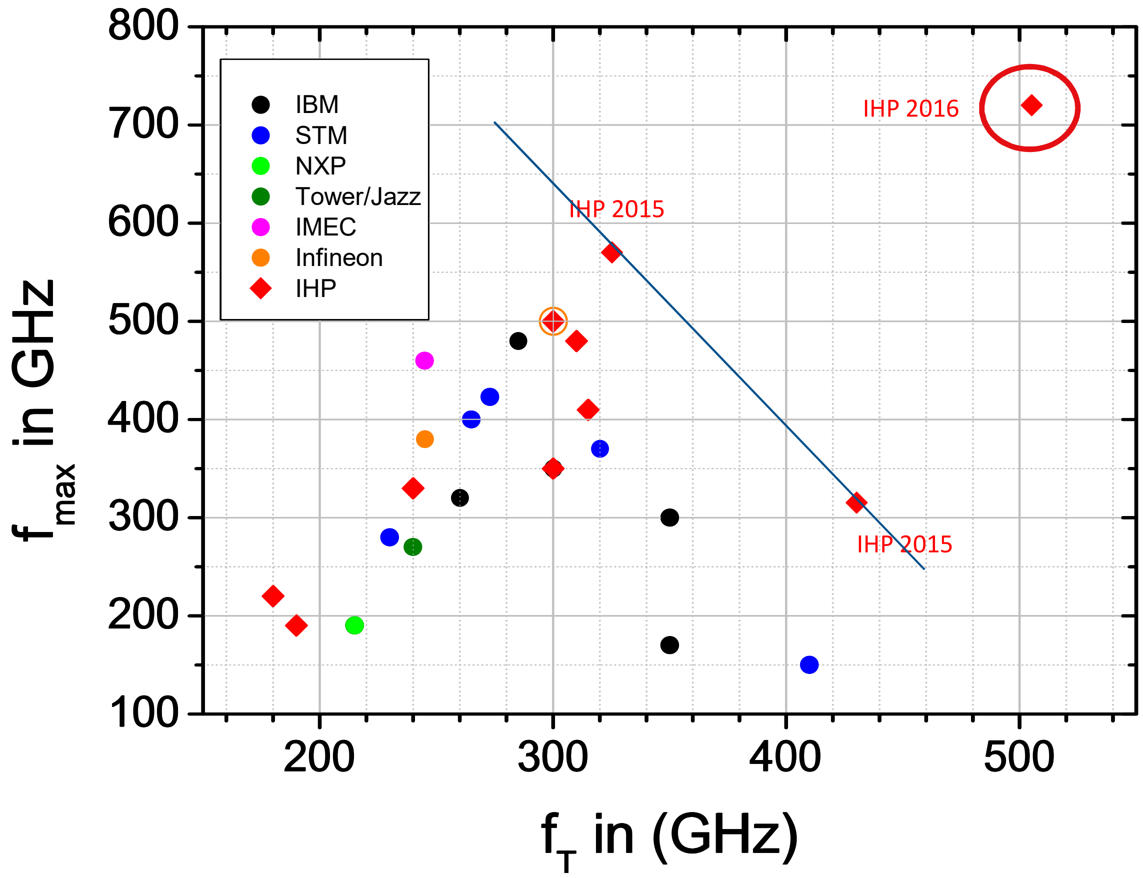
- R & D for wireless and broadband communication, health, security, space and industrial automation

Core Competencies

- Design of wireless systems and RF circuits
- Development of modular SiGe BiCMOS and Silicon Photonics
- Innovations with new materials and device concepts
- Preparation of ASIC prototypes and small series in an own pilot line

Schnellster siliziumbasierter Transistor der Welt

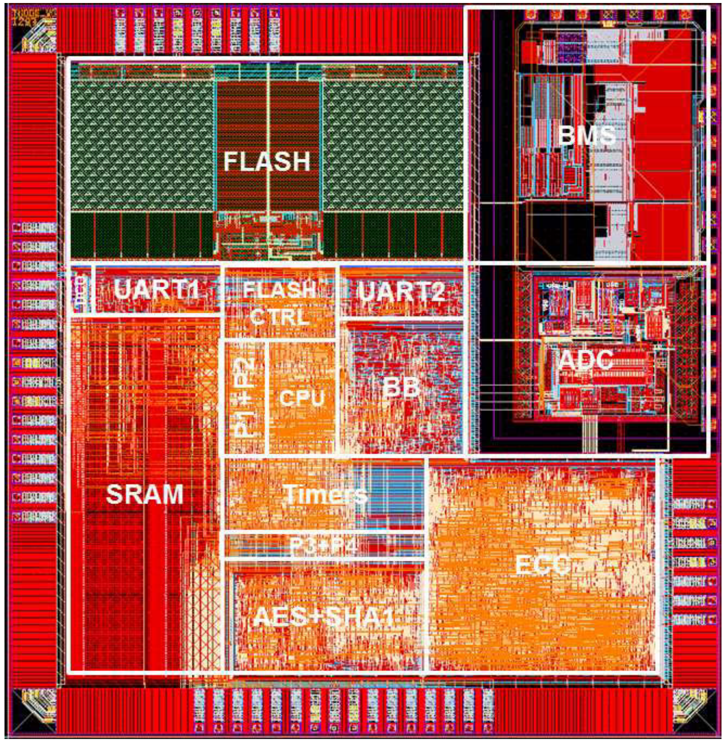
Vorgestellt vom IHP im Dezember 2016 in San Francisco:
720 Gigahertz max. Schwingfrequenz, 1,4 Picosekunden Schaltzeit



Der Rekordtransistor wurde im europäischen Projekt Dotseven erarbeitet.

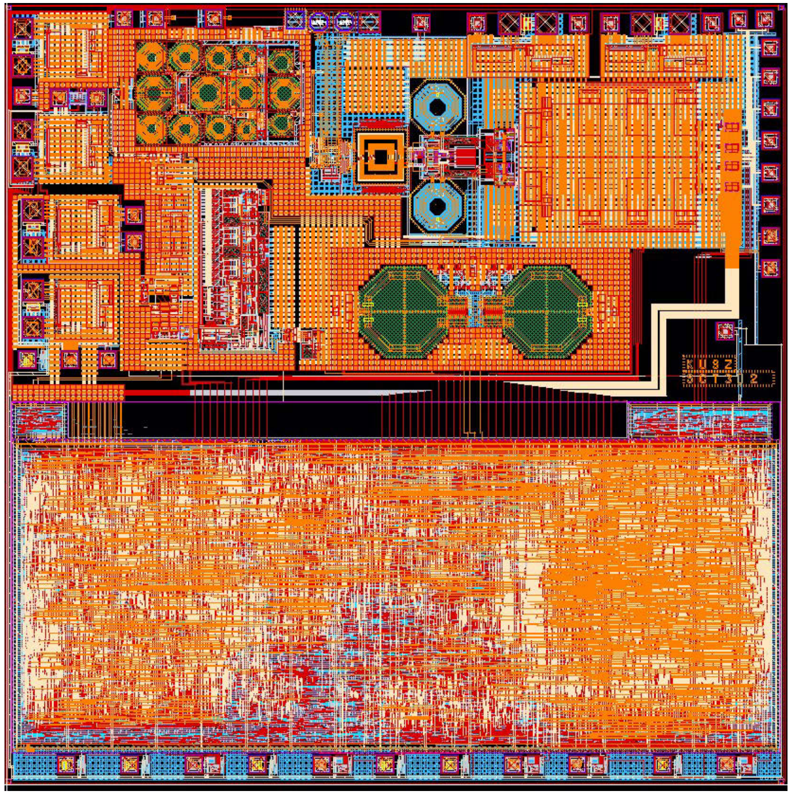
Sensor-Node based on MSX430 architecture (IHP430x_v6)

- Clock System (Clock Gating, diff. Clock Domains)
- Power Gating + Controller
- Integrated BMS (4 Channels)
- 32-bit Timer
- Package: QFN-64 (9x9 mm)
- Chip size: 31 mm²
- Core: ipms430x
- 16K RAM; 64KByte Flash + EDAC
- 4 channel ADC (12 bit)
- 2x SPI
- 4x GPIO's
- 2x UART
- 2x 16-bit Timer
- Crypto-Cores: AES-128, ECC-233, SHA-1
- Baseband MSSS
- Internal Clock Source (DCO)



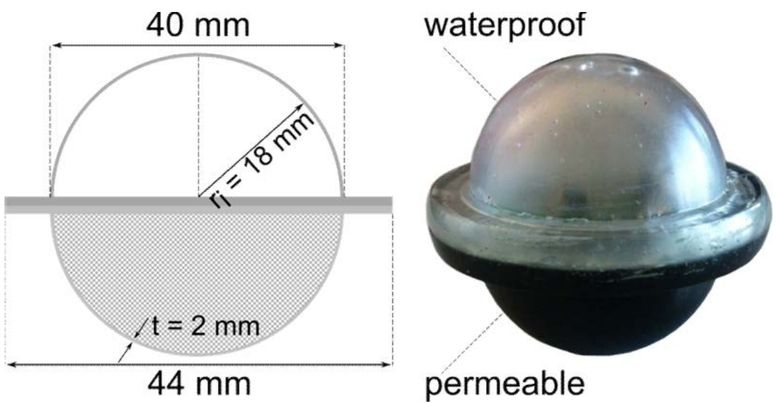
Application areas:
- Telemedicine and rehabilitation
- Environmental monitoring and agriculture
- Protection of critical infrastructure
- General IoT applications

Single Chip IR-UWB

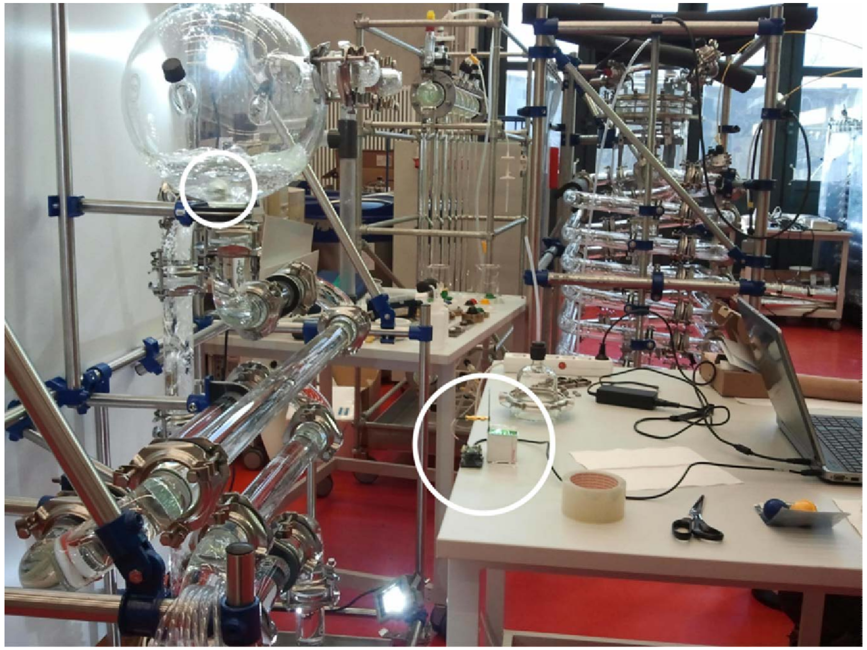


- Small size - 3.6 mm x 3.6 mm
- Large Integration = analogue HF frontend + digital baseband
- Low power consumption – 200 mW
- Transmission and reception at four frequency channels
- Support of multiple data rates

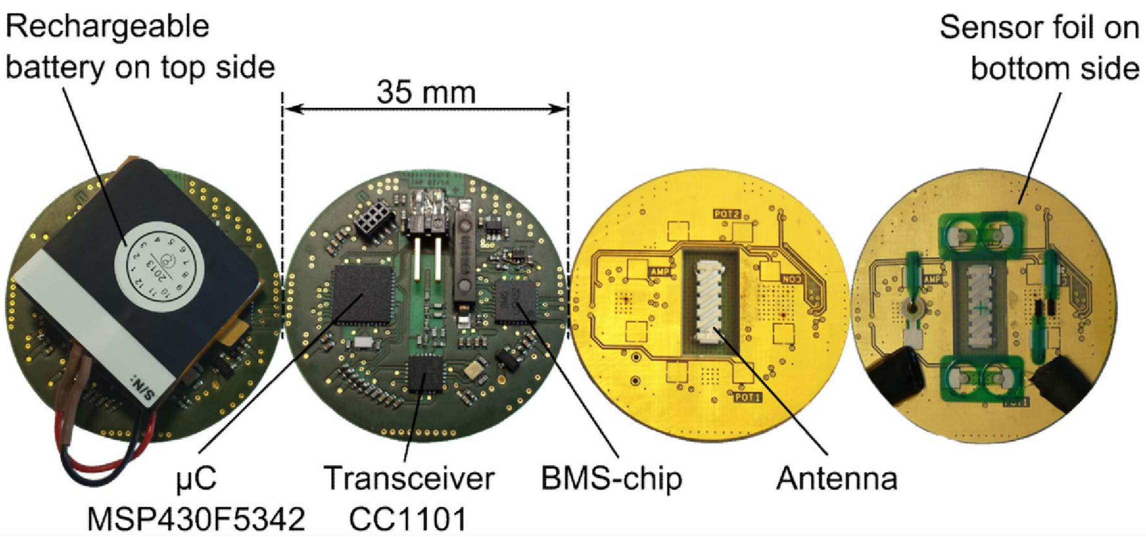
Bio-Reactor Application



Sensor Capsule



Pipe-Reactor



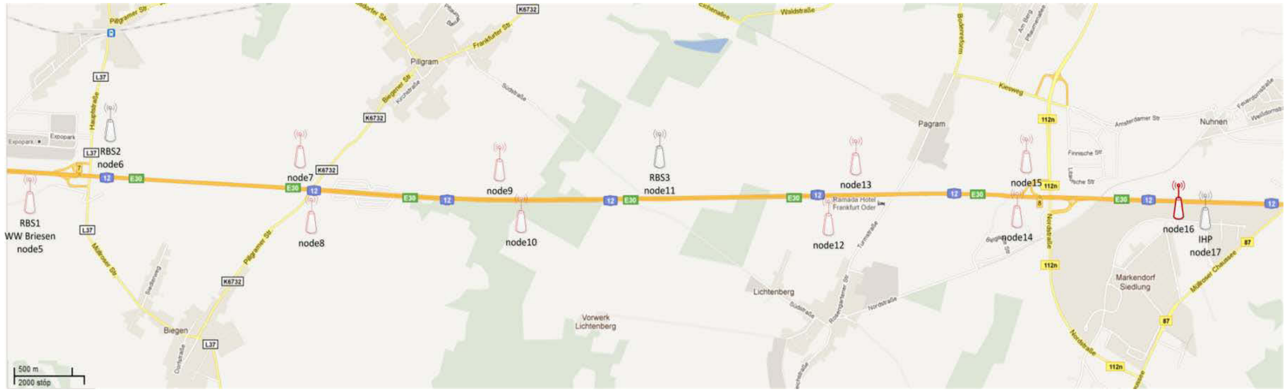
Electronic-Views

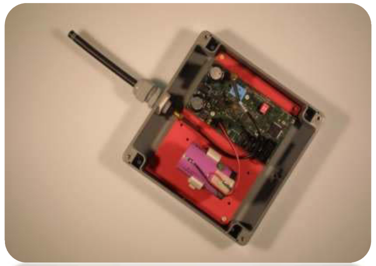
 | |

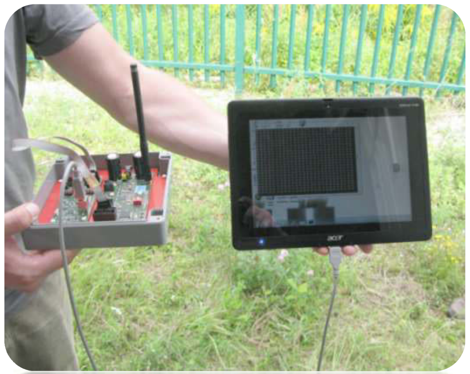
WSAN4CIP, monitoring of critical infrastructures

Monitoring the drinking water distribution network

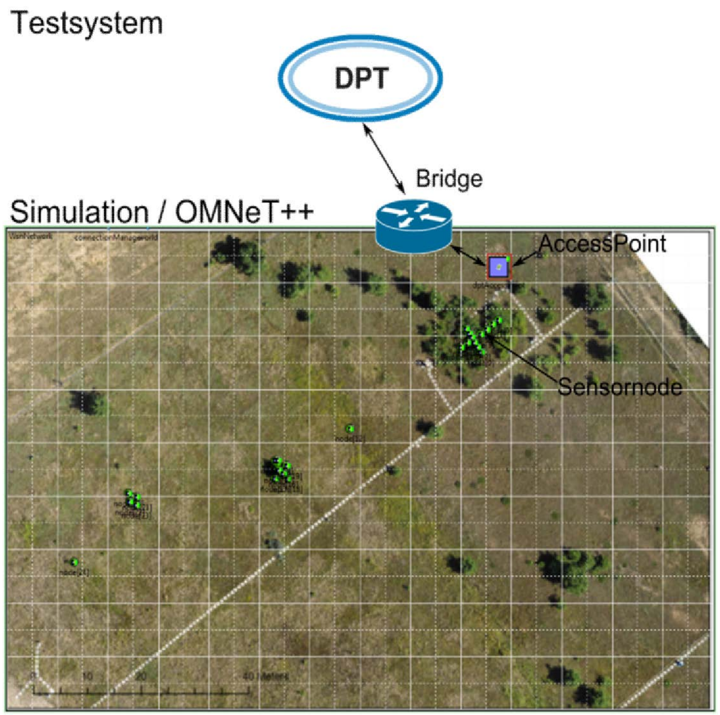
- Sparse multi-hop network with 12-15 long-range nodes
- Moderate data generation rate (seconds/tens of seconds)
- Node redundancy to increase reliability
- Monitoring of a 20km pipeline in Germany
- Reporting of operating state, alarm conditions and access control
- Integration in existing infrastructures







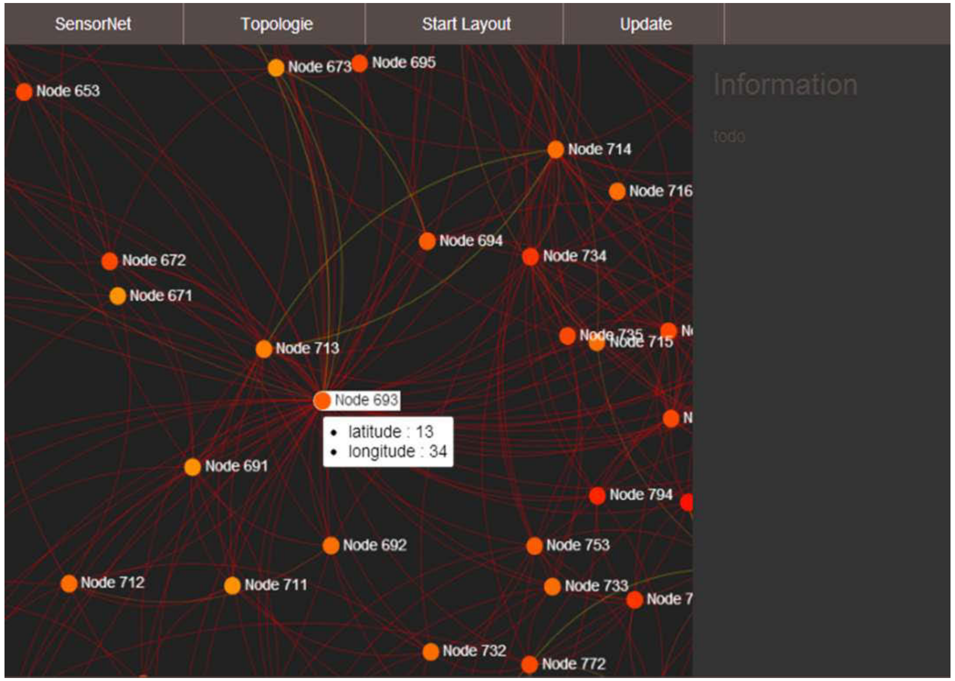
Environmental Monitoring within the Sense4U Project



Testnetz für biologische und hydrologische Messwerterfassung in einem Rekultivierungsgebiet in der Lausitz

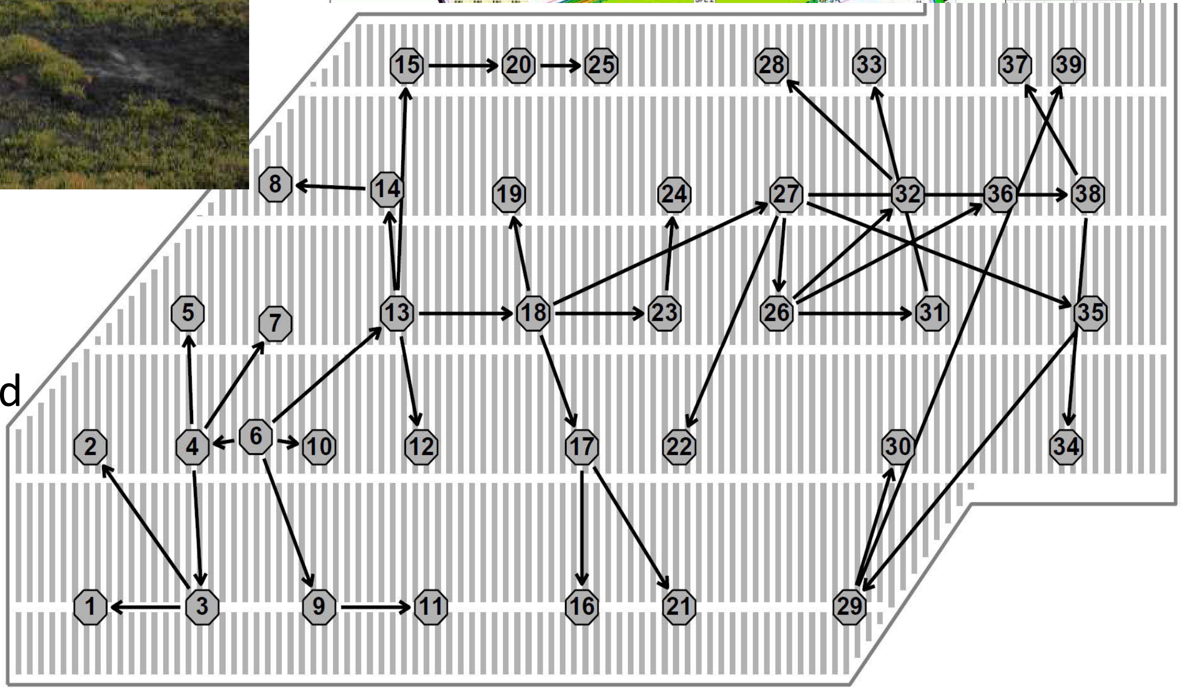
Die prototypische GUI zeigt die Link-Qualität-Indikatoren.

Die Verbindungsqualität wird durch unterschiedliche Farben dargestellt



 | |

SolarFlex: Sensor network to control solar power-plants



The solar power-plant is now in regular service and controlled by the Bluetooth network based on SFX self-healing

Electromagnetic Wave Propagation and Link-Budget

- Electromagnetic wave are used for wireless communication
  - The typical frequency range is in between 100 MHz and 10 GHz
  - In 5G higher frequencies up to 250 GHZ are proposed
- Electromagnetic wave are attenuated by several physical effects
  - Distance
  - Multi-Path propagation, Reflection, Diffraction ….
  - Material Interaction
- The Link budget is the sum of all amplifying and attenuating effects on the way from Sender to receiver
- The interaction between the electromagnetic waves and gasses and water is especially interesting
  - To determine the presence or absence of certain materials
  - To determine the concentration of those materials
  - In agriculture plants consist to more than 95% of water, thus determining the concentration of water allows the determination of the bio-mass
  - Unfortunately the correctness of the measurement is impacted by several side effect which has to be measured as well to finally calculate the correct bio-mass value

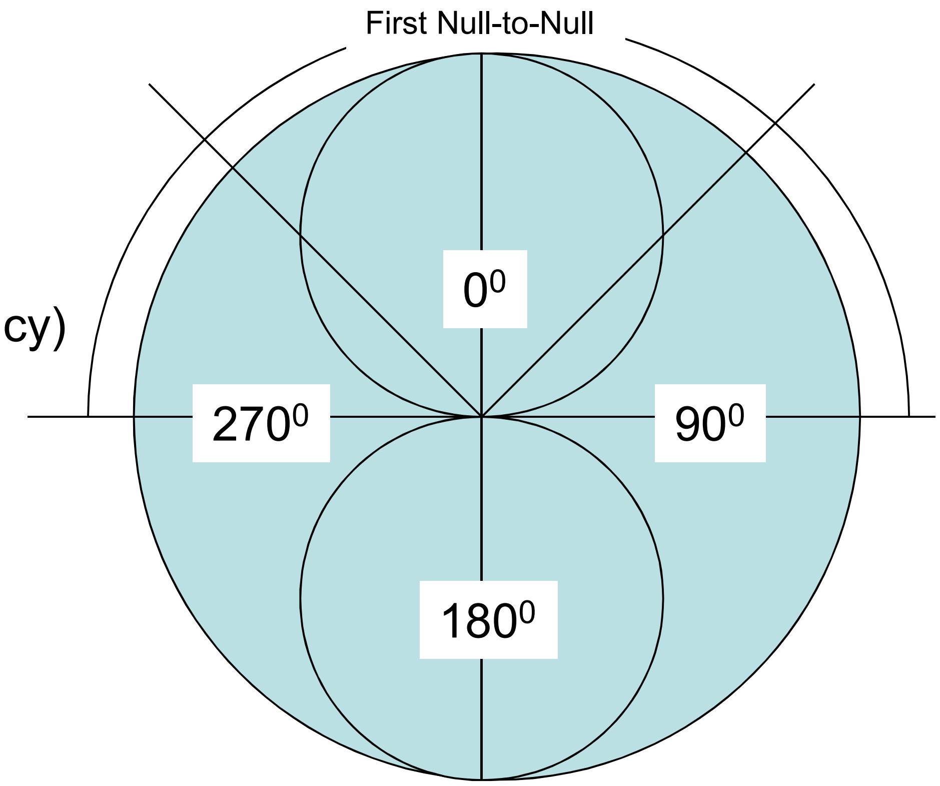
 | |

Antenna parameters

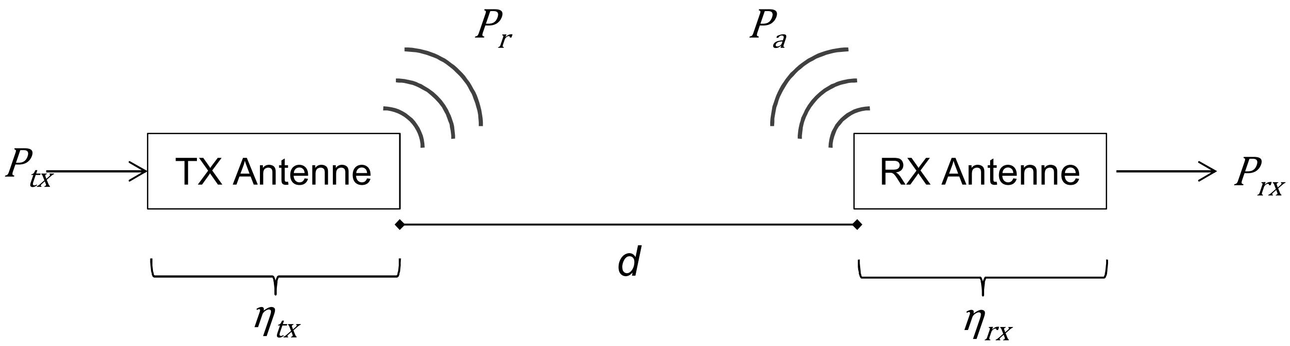
$G = 4\pi\eta A_w/\lambda^2$

G = Gain
η = loss-coefficient (efficiency)
A_w = electrical aperture
λ = wavelength

$A_w(G=1) = \lambda^2/4\pi\eta$



Friis Formula for „Link Budget Calculation" in Vacuum



- The optimal receive power P_{rx} :

$$P_{rx} = P_{tx} * (\lambda/4\pi d)^2 * G_{rx} * G_{tx}$$

- In logarithmic form:

$$P|_{dBm} = 10 * lg(P/1\ mW)$$

$$L_{path}|_{dB} = 20 * lg(4\pi d/\lambda)$$

$$L_{path}|_{dB} = 20 * lg(4\pi df/c)$$

$$P_{rx}|_{dBm} = P_{tx}|_{dBm} + G_{tx}|_{dBi} + G_{rx}|_{dBi} - L_{path}|_{dB}$$

Friis Formula in Real Case

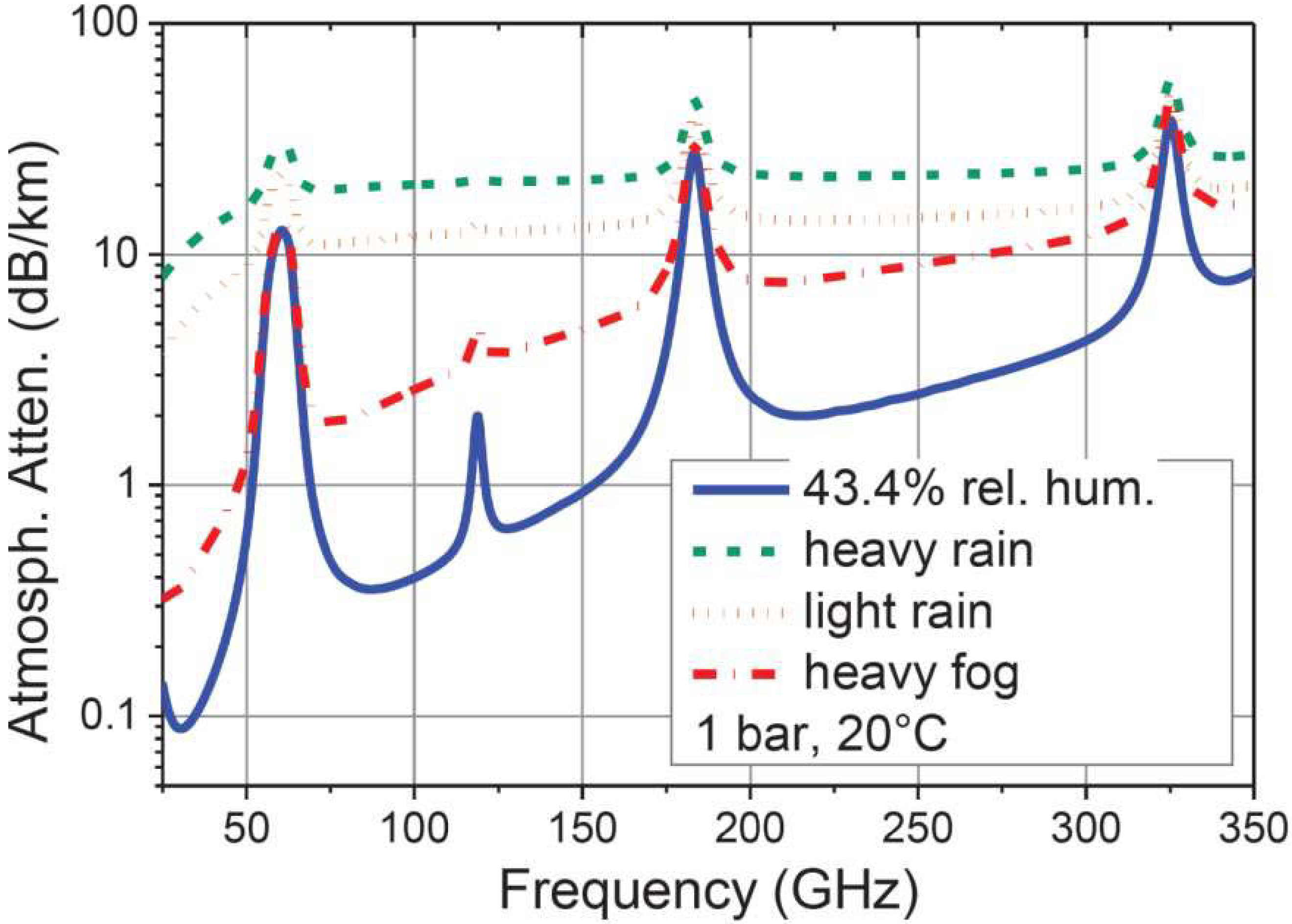
$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - L_{TX} - L_{FS} - L_{P} - L_{RX}$$

Where:

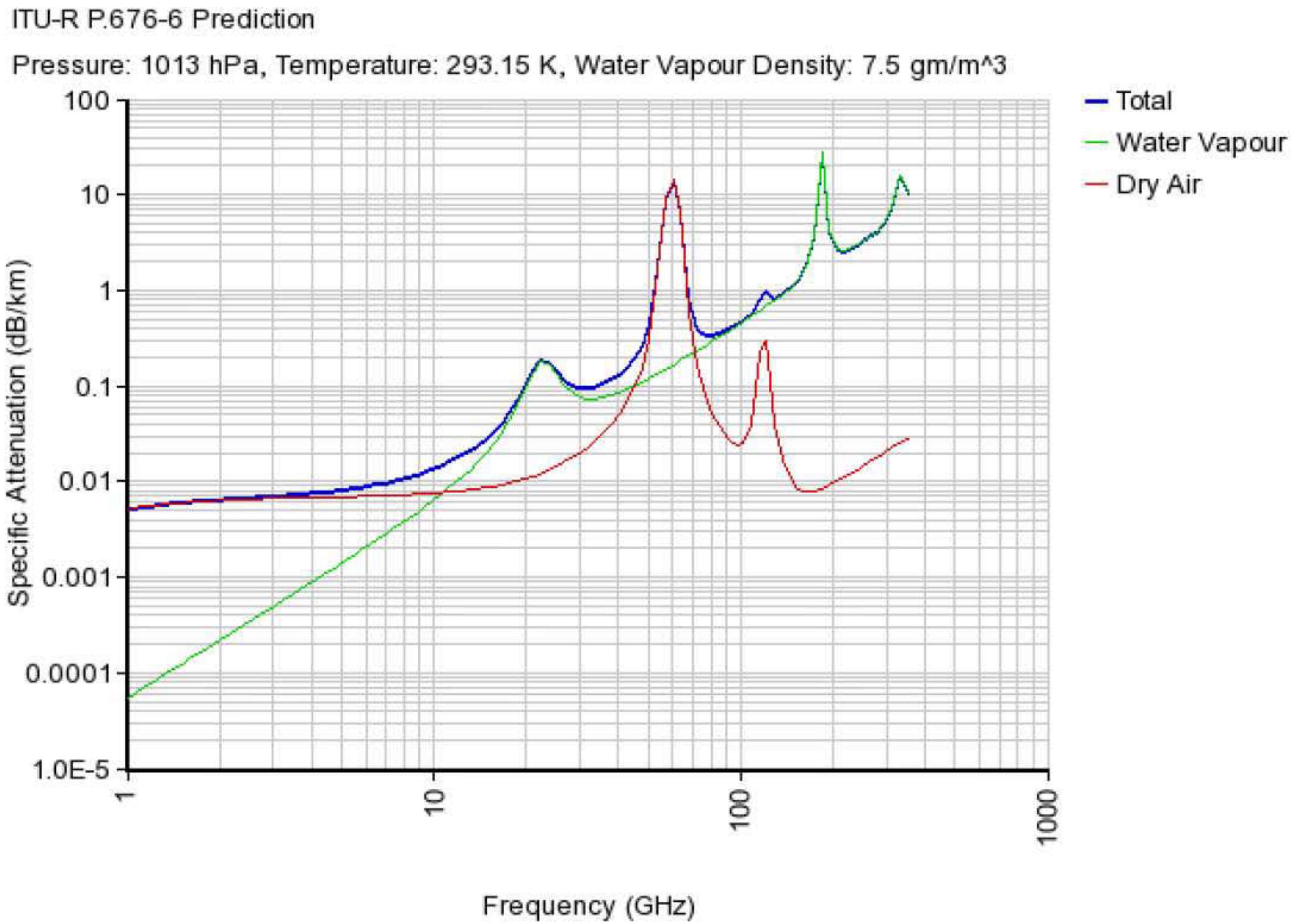
P_{RX} = received power (dBm)
P_{TX} = transmitter output power (dBm)
G_{TX} = transmitter antenna gain (dBi)
G_{RX} = receiver antenna gain (dBi)
L_{TX} = transmit feeder and associated losses (feeder, connectors, etc.) (dB)
L_{FS} = free space loss or path loss (dB)
L_{P} = miscellaneous signal propagation losses (these include fading margin, polarization mismatch, losses associated with medium through which signal is travelling, other losses...) (dB)
L_{RX} = receiver feeder and associated losses (feeder, connectors, etc.) (d)B

L_{FS} will be further increase by objects in the propagation path of the wave (Elliptic Curve). Therefore it is important to control the antenna heights, the beam angle (gain). In agriculture the antenna is close to the ground. In this case the attenuation is proportional to d^4 rather than d^2.

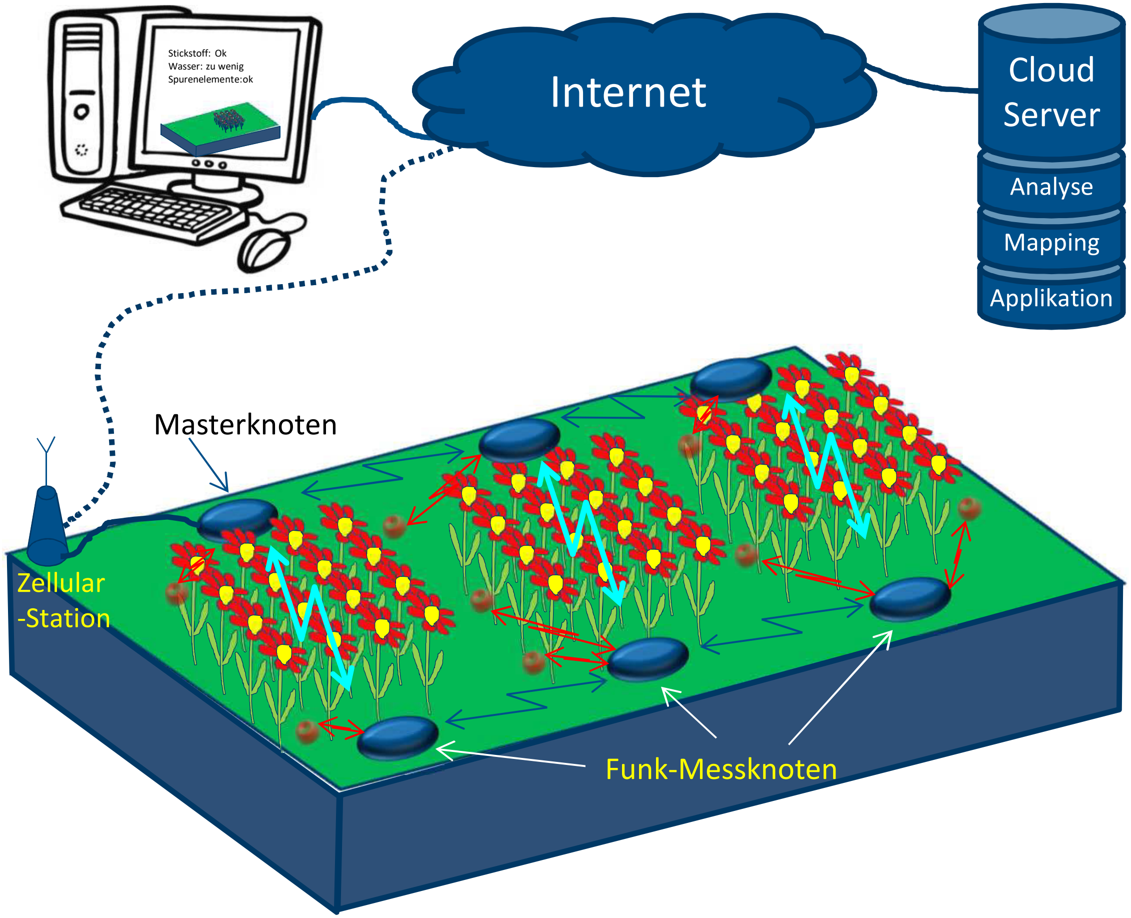
Material based Additional Attenuation Factors



ITU-R Modell for Attenuation in Air



Sensor Networks Topologies for Agriculture



Mobilfunk Anbindung

Daten-Funkstrecke Knoten-zu-Knoten, Referenz ohne Dämpfung

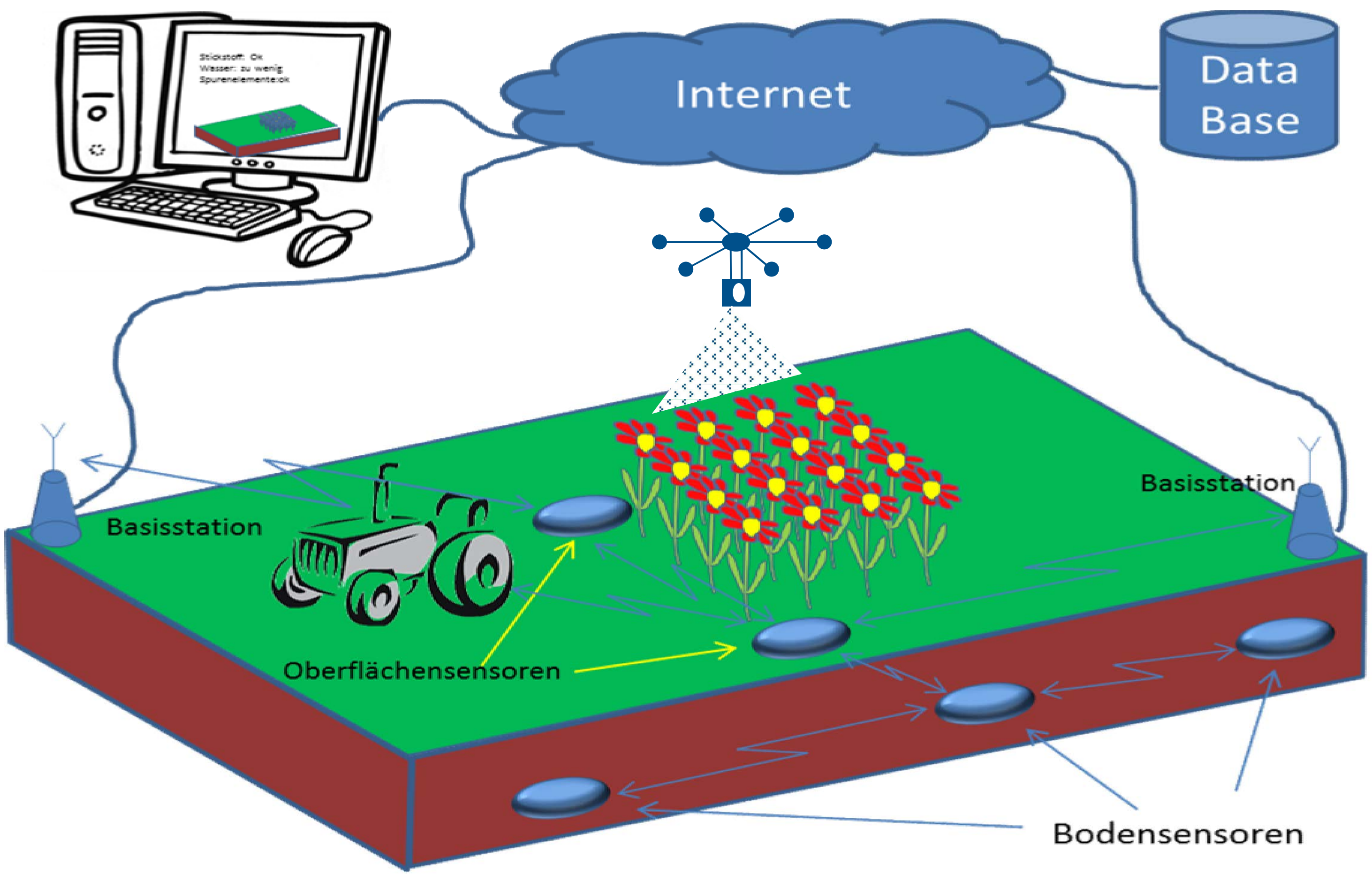
Mess-Funkstrecke Knoten-zu-Knoten mit Dämpfung durch Biomasse

BT-LE Funkstrecke Knoten-zu-Umweltsensoren

Integrated Communication and Sensing

- The previous picture shows of possible sensor network topology consisting of 3 subnets:
  - Cellular network between the Internet and the local base-station
  - The local communication network consisting of cluster nodes to collect the sensor data
  - The sensing nodes that collect the data and transmit it to the local nodes
- These networks can be quite different in using different standards to fulfill the respective tasks:
  - The cellular network has to connect the local network on a long distance (several km) and aggregates all data
  - The local network has a medium range (100-300m). It collects the data and performs in-network aggregation
  - The sensing network measures specific data, consolidates it and transmits it on a short distance (100m) to the local cluster nodes. The sensor nodes can sleep for long periods and wake up on special triggers (time, sensing value threshold, radio wake-up)
- We want to use the local network additionally for the measurement of the bio-mass since the transmission is directly impacted by attenuation cause by water

Interaction with Machines and other External Devices



Interaction with Machines and other External Devices by Radio Wake-Up

- In agricultural applications the sensors should fulfill several use-cases:
  - Monitoring of the soil parameters (also activity based e.g. during strong rainfall) as well as environmental relationships
  - Interact with agricultural machines to transmit specific values in (close) vicinity
- Since power consumption is a big issue the sensor nodes should (deep) sleep as long as possible. In deep sleep mode they consume only a view microwatt. In active mode the sensor nodes consume several miliwatt.

- Radio Wake-Up is a technology that can be used to continuously listen to the radio channel but consuming only little energy. This limits the Wake-Up system both in sensitivity and data-rate, but allows asynchronous interaction.
- If a machine approaches a sensor node it can transmit a wake-up signal and the wake-up system switches the main communication system on. As soon as data is transmitted the system goes back to sleep.
- This approach can also be used for any other device like handhelds, drones etc.

- The big issue with wake-up radio technology today is its limitation in sensitivity. With only apr. -70 dBm the maximum distance is limited to about 100 m. If sensor nodes are in the ground only a view m can be achieved.

Conclusions

- This talk presented „work in progress“ in several aspects of using innovative techniques for agricultural sensor networks.
- At first we presented some of our sensor network approaches based on own highly integrated sensor nodes
- Second we analyzed electromagnetic wave propagation to find ways to determine bio-mass from radio measurement.
- This measurements should be conducted in line such that no additional sensing node is necessary.
- Finally we presented the idea of Radio Wake-Up technology to allow for asynchronous operation and to extend the node lifetime significantly

Thank you for your attention!

IHP – Innovations for High Performance Microelectronics
Im Technologiepark 25
15236 Frankfurt (Oder)
Germany
Phone: +49 (0) 335 5625
Fax: +49 (0) 335 5625
Email:

www.ihp-microelectronics.com

innovations
for high
performance
microelectronics

Member of
Leibniz Association